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The Nocturnal Emergence Activity Rhythm in the Cumacean *Dimorphostylis asiatica* (Crustacea)

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Abstract. The crustacean *Dimorphostylis asiatica* inhabits the sublittoral zone and actively swims in the water at night. Males are positively phototaxic, and can be collected on the surface by using a light at night. The timing of this emergence was investigated in the field. Nearshore collections of males have demonstrated a clear rhythmic pattern, with emergence synchronized with both day-night and tidal cycles. The remarkable feature of this record was that the tidal aspect of the pattern was modified seasonally. While emergence was strongly synchronized with high tide during the winter and spring, tidal synchrony was scarcely detected in summer and autumn. Environmental factors that affect the seasonal modification of the activity pattern are still unknown.

Introduction

On intertidal and estuarine shores, organisms are exposed to periodical changes due to tides and the day-night cycle. These organisms have often evolved, as an adaptation to these environments, timing of activities synchronized with both daily and tidal cycles. The activity patterns differ, reflecting the degree of synchronization with these environmental factors, *i.e.*, daily rhythms (Enright and Hamner, 1967; Hammond and Naylor, 1977), tidal rhythms (Morgan, 1965; Klapow, 1972), and timing with both components (Barnwell, 1966; Benson and Lewis, 1976).

Although seasonal modification of rhythmic behavior is well documented for terrestrial species (see reviews by Saunders, 1976, and Gwinner, 1981), few investigations have been carried out on such aspects of intertidal and estuarine organisms. The present study deals with long-term field observations on the nocturnal crustacean *Dimorphostylis asiatica* inhabiting the nearshore sublittoral zone in Japan. The nocturnal vertical migration of other cumaceans in the field was previously reported by Corey (1970).

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Materials and Methods

Adult males of *Dimorphostylis asiatica* (Order: Cumacea), 2–4 mm in body length, living in the Inland Sea of Japan, were studied. The animals hide in the mud flat in the daytime. They swim actively after sunset, and only the males are attracted to light. In spite of many plankton tows, no individuals were caught during the day, so the study focused on nighttime activity. A tungsten torchlamp (100 V, 200 W) was placed on the edge of a floating pier (about 10 m from shore), and the light beam was directed to the surface of the sea. The maximum depth around the collection site is about 3–4 m at the spring high tide. *D. asiatica* individuals swimming under the light can be easily distinguished by their bright yellow color and unique pattern of swimming. As soon as they appeared in the illuminated collection area (about 1 m × 2 m in surface area), the animals were caught with a flat hand net (10 cm in diameter, with mesh size of about 1 mm) and brought to the laboratory.

Collections were made for 30 min every hour from sunset until sunrise, after which few *D. asiatica* individuals were seen near the surface of the water. Following each 30-min collection, the electric torch was turned off. Nightly collections spanning more than two weeks were carried out seven times (4–22 Mar. 1987; 1–16 May 1987; 28 June 28 to 6 Aug. 1987; 11 Sep. to 7 Oct. 1987; 5–20 Nov. 1987; 5–20 Jan. 1988; 3–18 Mar. 1988).

Times of sunset (SS), sunrise (SR), high water (HW1, HW2), and low water (LW1, LW2) were based on data published by the Japan Meteorological Agency.

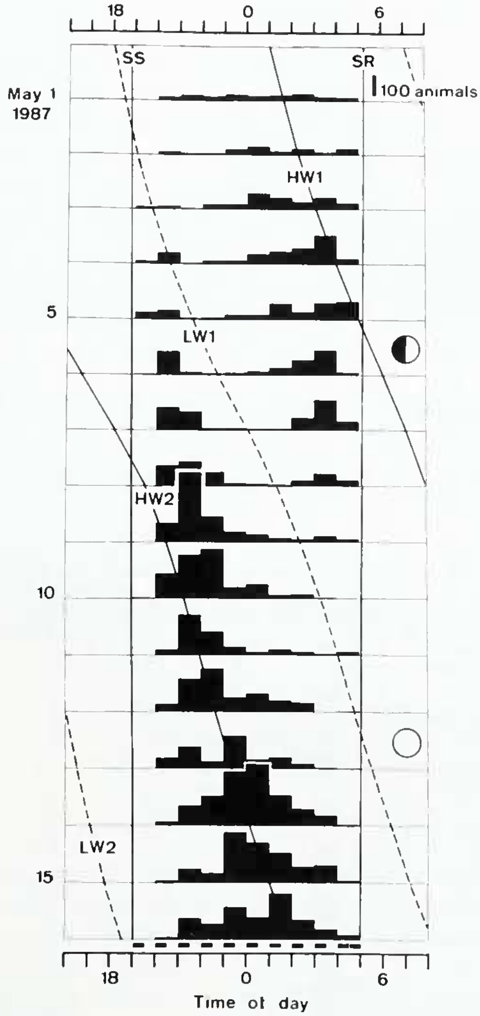

Figure 1. The emergence pattern in May (1–16 May 1987) as determined by the number of *Dimorphostylis asiatica* individuals captured every night from 19:00 to 05:00. The actual times of the collections are indicated by the bars on the time scale. SS: sunset; SR: sunrise; HW1 and HW2: high tides; LW1 and LW2: low tides.

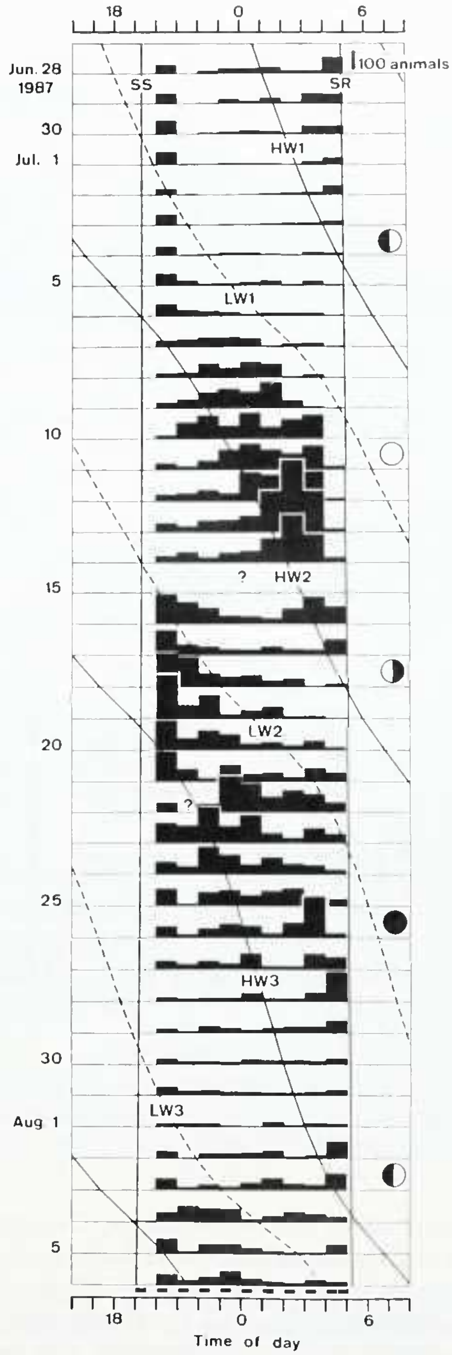

Figure 2. The pattern of *Dimorphostylis asiatica* emergence in July (28 June–6 Aug. 1987). Collections were made from 19:00 to 05:00. ?: indicates that no collections were made on 15 August due to bad weather. Other symbols as in Figure 1.

Results and Discussion

The emergence patterns of *D. asiatica* were summarized in each season.

Emergence pattern in March and May

Figure 1 shows the number of animals collected during each hour of the night in May. Most animals were collected near the time of the night high tide. When high tides (HW1 and HW2) occurred around the time of sunrise and sunset (6–7 days surrounding the first quarter of the moon), the activity exhibited two peaks in the night, one shortly after sunset and another before sunrise. Collections in March showed a similar pattern (data not shown).

Emergence pattern in July

The tide-correlated timing, which was clearly evident in Figure 1, became vague during the summer (Fig. 2). Until 4 July, bimodal peaks of emergence activity ap-

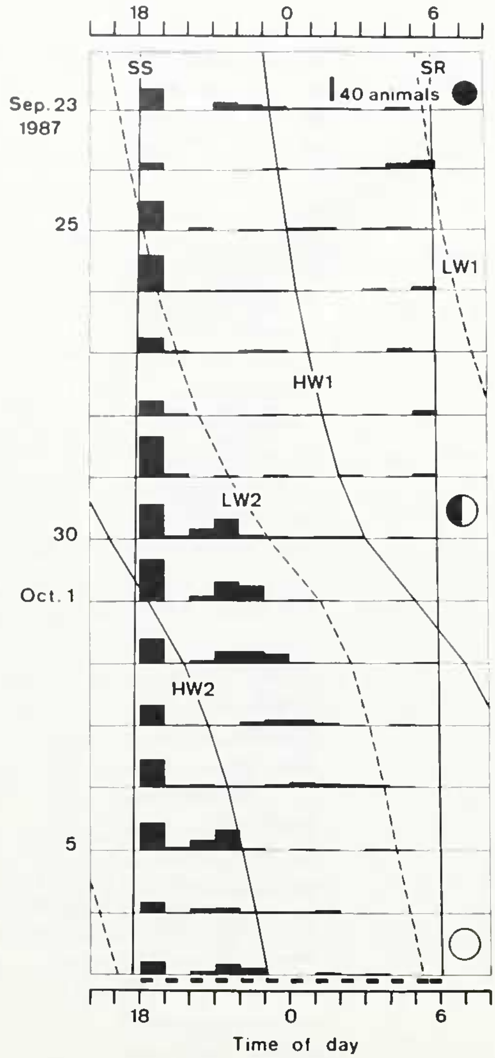

Figure 3. The pattern of *Dimorphostylis asiatica* emergence in September–October (23 Sep.–7 Oct. 1987). Collections were carried out from 18:00 to 06:00. Symbols as in Figure 1.

peared after sunset and before sunrise. Thereafter, those peaks of activity disappeared, and most of the emergence took place on the ebb tide (5–10 July). Compared with the data illustrated in Figure 1, the activity pattern in this season was not as clearly synchronized with the time of high water. For six days surrounding the last quarter moon (18 July), large peaks of emergence were recorded just after sunset. Tidally correlated timing of emergence was weak and disappeared thereafter.

Emergence pattern in September and November

Tidally synchronized timing was scarcely detectable in either the data from September or from November; the pattern is characterized instead by a peak coinciding with the time of dusk (Fig. 3).

The pattern in January

The data obtained in January (Fig. 4) show the reappearance of tidally correlated timing in the emergence activities. Although the tidal component is not strongly distinguished in the first half of the record, it constitutes the main activity in the latter half of the data. Figure 4 further shows that the timing was gradually modified from being dusk-correlated to tide-synchronized. The time difference between sunset and the following activity peak (see the data of 5–14 January) was an hour or two greater in January than at other seasons (Figs. 1, 3).

Number of animals emerging per day through a year

The number of animals that were captured on each night is summarized in Figure 5. There was no clear ev-

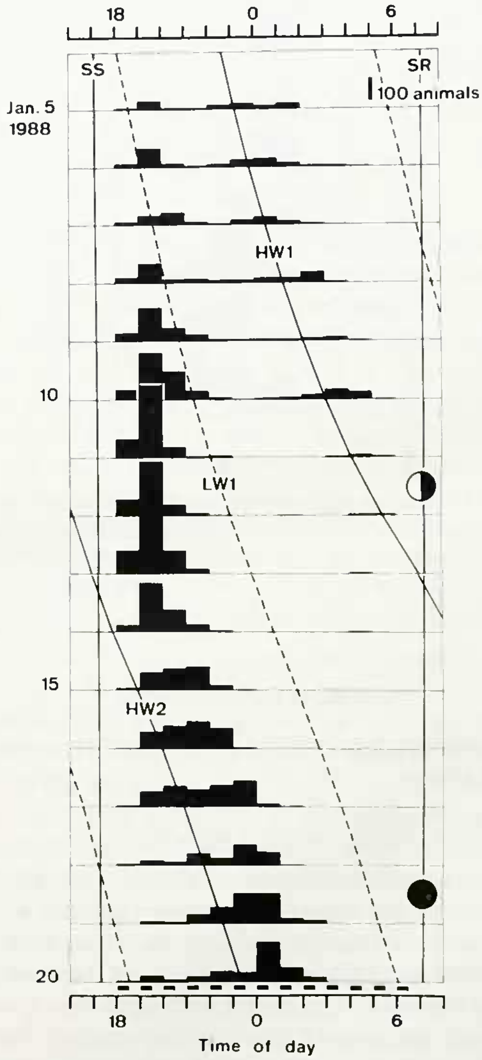

Figure 4. The pattern of *Dimorphostylis asiatica* emergence in January (5–20 Jan. 1988). Collection times were 18:00–06:30. Symbols as in Figure 1.

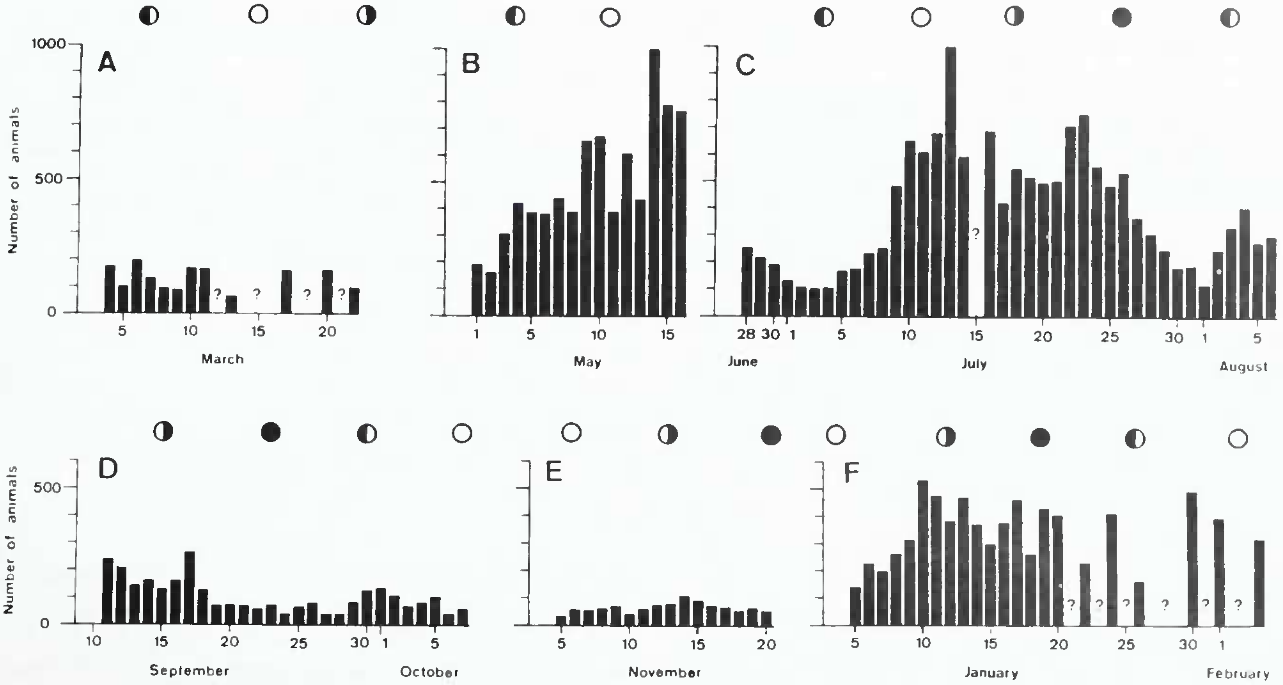

Figure 5. The number of animals captured on each night of collection. A: the data from the first series of investigations; B: the second; C: the third; D: the fourth; E: the fifth; F: the sixth. Abscissa: the dates. Ordinate: number of males. ?: signifies that no collections were made on that date.

idence of lunar or semilunar rhythmic patterns. Although there is some suggestion of a monthly cycle in the record of June–August (Fig. 5C), similar trends are not clearly evident at other seasons.

As indicated by the present observations, a distinct emergence rhythmicity was observed for the male population of *D. asiatica* through the year in the field. The swimming activity was synchronized with environmental day-night and tidal cycles, showing a complex activity pattern. The remarkable feature of the records is the annual modification of the tidal timing involved in the pattern.

To explain such a difference in the activity patterns, it is possible to postulate that the animals synchronize their activity with seasonally changing environmental factors. Intertidal organisms respond to physical factors associated with on-shore tides, *e.g.*, changes of hydrostatic pressure (Enright, 1962; Morgan, 1965; Naylor and Williams, 1984) or cycles of water turbulence (Enright, 1965). If such environmental factors fluctuate seasonally, they might affect the timing of the animals, resulting in the different activity pattern in each season. However, the similar pattern of the fluctuation of tidal amplitude in spring and autumn (not illustrated) makes it difficult to consider that the emergence pattern of *D. asiatica* is directly affected by such factors.

Another possibility is that the internal timing of animals was somewhat different in each season, which might cause the annual modification of the emergence pattern in this population. This possibility is presently under investigation in the laboratory.

Acknowledgments

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Literature Cited

Barnwell, F. H. 1966. Daily and tidal patterns of activity in individual fiddler crab (genus *Uca*) from the Woods Hole region. *Biol. Bull.* **130:** 1–17.

Benson, J. A., and R. H. Lewis. 1976. An analysis of the activity rhythm of the sand beach amphipod, *Talorchestia quoyana*. *J. Comp. Physiol.* **105:** 339–352.

Corey, S. 1970. The diurnal vertical migration of some Cumacea (Crustacea, Pericarida) in Kames Bay, Isle of Cumbrae, Scotland. *Can. J. Zool.* **48:** 1385–1388.

Enright, J. T. 1962. Response of an amphipod to pressure changes. *J. Comp. Biochem. Physiol.* **7:** 131–145.

Enright, J. T. 1965. Entrainment of a tidal rhythm. *Science* **147:** 864–867.

Enright, J. T., and W. M. Hamner. 1967. Vertical diurnal migration and endogenous rhythmicity. *Science* **157:** 937–941.

Gwinner, E. 1981. Annual rhythms: perspective. Pp. 391–410 in *Biological Rhythms. Handbook of Behavioral Neurobiology,* Vol. 4, J. Aschoff, ed. Plenum Press, London.

Hammond, R. D., and E. Naylor. 1977. Effects of dusk and dawn on locomotor activity rhythms in the Norway lobster *Nephrops norvegicus. Mar. Biol.* **39:** 253–260.

Klapow, L. A. 1972. Natural and artificial rephasing of a tidal rhythm. *J. Comp. Physiol.* **79:** 233–258.

Morgan, E. 1965. The activity rhythm of the amphipod *Corophium voltator* (Pallas) and its possible relationship to changes in hydrostatic pressure associated with tides. *J. Animal Ecol.* **34:** 731–746.

Naylor, E., and B. G. Williams. 1984. Environmental entrainment of tidally rhythmic behavior in marine animals. *Zool. J. Linnean Soc.* **80:** 201–208.

Saunders, D. S. 1976. *Insect Clocks.* Pergamon Press, London.